

# HIGH ENERGY SOLID PROPELLANT

## FIELD OF THE INVENTION

The present invention provides a solid propellant for use in rocket engines. In particular, the present invention provides a high energy solid propellant comprised of an oxidizer, fuel and binder, wherein the fuel is encapsulated or microencapsulated. This encapsulation or microencapsulation allows for use of a highly energetic fuel component, while avoiding uncontrollable reactivity, and provides a propellant having an exceptionally high specific impulse.

## BACKGROUND OF THE INVENTION

A solid propellant is conventionally comprised of an oxidizer, fuel and a binder. Generally, in a solid propellant comprised of 72% oxidizer, 16% fuel and 12% binder, an  $I_{sp}$  of around 272 seconds is common. Conventionally, solid propellant binders, such as PBAN (polybutadiene acrylonitrile copolymer) have been used, as well as HTPB (hydroxyl-terminated polybutadiene).

A significant problem with conventional solid propellants is the phenomena of two-phase flow. Aluminum is added to increase the thermodynamic energy of the propellant. However, the kinetics of the rocket combustion process can lead to liquid, unreacted aluminum emerging from the nozzle with a commensurate decrease in thrust. The particle size of the aluminum can be reduced such that this phenomena in principle is minimized, however, a passive oxide layer (ca. 20 Å) is immediately formed on the small

particles, which much be destroyed within the combustion chamber. Again, the energy gain is lost by the subsequent “after-burning”.

It is an object of the present inventors to overcome the deficiencies of the conventional solid propellants, as mentioned above. In particular, it is an object of the present invention to provide a highly reactive solid propellant that avoids the problems traditionally associated with two-phase flow.

## SUMMARY OF THE INVENTION

In order to achieve the object of the present invention, as described above, the present inventors provide, in a first embodiment, a high energy solid propellant comprising:

- (a) an oxidizer comprised of ammonium perchlorate, ammonium nitrate or ammonium dinitramide;
- (b) a binder comprised of polymeric hydrocarbons or polymers; and
- (c) a fuel comprised of lithium hexahydridoborane or lithium hexahydridoalane, wherein the fuel and/or solid propellant is encapsulated or microencapsulated such that the propellant grain is fabricated without diminution of its energetic properties. .

In a second embodiment, a high energy solid propellant according to the first embodiment above is provided, wherein the binder is PDCPD (polydicyclopentadiene), polyethylene, polystyrene, or low molecular weight polyethylene.

In a third embodiment, a high energy solid propellant according to the first embodiment above is provided, wherein the fuel is comprised of lithium hexahydridoborane and aluminum, or LHA (lithium hexahydridoalane) and aluminum.

In a fourth embodiment, a high energy solid propellant according to the second embodiment above is provided, wherein fuel is comprised of lithium hexahydridoborane and aluminum, or LHA (lithium hexahydridoalane) and aluminum.

In a fifth embodiment of the present invention, the high energy solid propellant of the first embodiment is provided, wherein the propellant comprises 60-80 wt% oxidizer, 5-30 wt% fuel, and 5-15 wt% binder.

In a sixth embodiment of the present invention, the high energy solid propellant of the first embodiment is provided, wherein the propellant comprises 65-75 wt% oxidizer, 10-25 wt% fuel, and 10-15 wt% binder.

In a seventh embodiment of the present invention, the high energy solid propellant of the first embodiment is provided, wherein the propellant comprises 70-75 wt% oxidizer, 15-25 wt% fuel, and 12 wt% binder.

#### DETAILED DESCRIPTION OF THE INVENTION

$I_{sp}$ , specific impulse, is defined as force/mass flow rate. In the context of solid propellants used in rocket engines, the specific impulse is (force/mass of solid propellant) x time. Specific impulse is an important characteristic of a solid propellant, in that it defines the appropriate mission for a given rocket, as rockets are mass-limited devices.

The more inherent energy that is present per mass, the greater the payload, or the greater the range of a given device.

Conventional solid propellants have attained  $I_{sp}$ 's of as much as 272 seconds. In contrast, the present invention provides a solid propellant comprising PDCPD, LHA and an oxidizer. In such a composition, the  $I_{sp}$  can be increased to as much as 310 seconds.

In the present invention, oxidizer such as ammonium perchlorate, ammonium nitrate and ammonium dinitramide may be used. For the binder, polymeric hydrocarbons are preferred. In particular, PDCPD (polydicyclopentadiene), polyethylene, polystyrene and LMWPE (low molecular weight polyethylene) are preferred. As the fuel component of the solid propellant, LHB (lithium hexahydridoborane) and LHA (lithium hexahydridoalane) are used.

Lastly, it is essential that the fuel component is encapsulated, or preferably microencapsulated such that the propellant grain is fabricated without diminution of its energetic properties. The propellant is comprised of 60-80% oxidizer, 5-30% fuel, and 5-15% binder; more preferably 65-75% oxidizer, 10-25% fuel, and 10-15% binder; most preferably 70-75% oxidizer, 15-25% fuel, and 12% binder.

As the high energy solid propellant is very reactive, an air barrier or coating is applied to either the fuel component alone, or to the entire propellant, so as to encapsulate same, to prevent reaction thereof with foreign sources. In particular, microencapsulation of the solid propellant is preferred. Microencapsulation may be achieved by, for example:

- 1) The high energy solid fuel ingredient is precipitated out of solution upon reaction with the alkyl lithium compound and dissolved lithium aluminum hydride in

appropriate solvents. If an appropriate polymer, wax, or compound is dissolved in the solvent system, the high energy solid propellant will microencapsulate as it precipitates.

2) The high energy solid fuel ingredient is manufactured as detailed in 1) above, without the encapsulating agent. The reaction mass is filtered, rinsed multiple times and suspended in an appropriate inert solvent into which an encapsulating agent (see above) is added by dissolution. This slurry is then spray-dried to its final state in warm air.

3) The high energy solid fuel ingredient suspension formed in 2) above is added to an immiscible solvent which contains the dissolved encapsulating agent (see above). This two-phase system is shaken to cause the particles to contact the encapsulation agent and thus form the microencapsulated system. The product is filtered and dried as normal.

All three of the above methods may form a free-flowing powder of LHA or LHB that is atmospherically unreactive, and thus useful in making the high-energy solid propellant of the present invention.